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**Research Article**

# EVALUATION OF VERTICAL DISTRIBUTION OF AVAILABLE POTASSIUM AND SULPHUR BY USE OF DIFFERENT EXTRACTANTS IN SOILS OF CHILKAHAR BLOCK OF BALLIA DISTRICT UTTAR PRADESH

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**Abstract:** Depth vise distribution of different forms of potassium and sulphur in soils of Chilkahar block of Ballia district was analysed by collection of depth-wise soil samples from two different villages (Kureji and Palta) by use of standard method. Soil samples from both villages expess that soil pH ranges from 6.2-7.4, EC 1.001-1.004 $dSm^{-1}$, organic carbon 0.03-0.40 % and by use of different extractants for available K and S *viz.* $NH_4OAc$ extractable-K 169.2 - 347.2 kg $ha^{-1}$, 0.01 M $CaCl_2.2H_2O$ extractable-K 78.2 -152.6 kg $ha^{-1}$, EDTA extractable-K 66.8 -116.6 kg $ha^{-1}$, water soluble-K 160.2-214.0 kg $ha^{-1}$, $HNO_3$ extractable-K 186.0 - 288.0 kg $ha^{-1}$, Mehlich III extractable-K 65.2 -128.0 kg $ha^{-1}$, and 1 M NaCl extractable-K 95.0 -160.0 kg $ha^{-1}$, and amount of $CaCl_2$ extractable-S was 5.0-6.3 mg $kg^{-1}$, $NaHCO_3$ extractable-S 4.8-5.2 mg $kg^{-1}$, KCl extractable-S 4.0 - 5.2 mg $kg^{-1}$, HCl extractable-S 2.3- 3.0 mg $kg^{-1}$, Morgan's reagent extractable-S was 6.0- 6.8 mg $kg^{-1}$ respectively.

**Keywords:** *Extractants, Available sulphur, Available potassium, Soil depth*

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## Introduction

Soil available K is well known to exist in different forms *viz*., water-soluble, exchangeable, non-exchangeable, acid soluble, EDTA, NaCl soluble and as a part of the mineral lattice. Water-soluble and exchangeable forms of potassium are of prime importance as far as their availability is a concern to plants. The knowledge of different forms of K in soil and their vertical distribution in soils assist in assessing long-term potassium availability and making judicious fertilizer recommendations for efficient different crop production. Historically, low application rates of K in crops have led to over-dependence on the native soil reserve K [1]. Due to variation in land elevation and cropping sequence in the diffenet zone, various forms of K may change and affects its availability in soil. Relative abundance of different forms of soil K determines its supplying capacity and availability to crops. Therefore, cropping without potassium application depletes plant-available K in soils in the long run and more rapidly so, at high fertility levels [2]. Knowledge of quantitative magnitude of different K forms in soils and the interrelationship among them is important for the assessment of the long-term availability of K in soil. Similarly, sulfur is also well known fourth important as secondary nutrient element in addition to nitrogen, phosphorus, and potassium. The deficiency of sulphur in soils and plants is being reported by several parts of the country. Sulphur is occurring in soils in both organic and inorganic forms but in most soils, organically bound sulphur is the dominant fraction of sulphur, combined with carbon, nitrogen and hydrogen. The inorganic forms of sulphur in soil consist mainly of SO-S. Sulphur adsorbed as $SO_4$- ions is reduced in plants and incorporated in organic compounds, proteins are the compounds in which most of the sulphur of plant tissue is incorporated. In soil, sulphur can be broadly grouped into total S, organic S, non-sulphate S, available S and water-soluble S. The nature and amounts of various forms of S depend on variation in soil texture, pH, calcium carbonate, organic matter, and other soil characteristics [3]. Both inorganic and organic forms and the proportion of inorganic to organic sulphur varies widely depending upon the nature of soil, its depth and management factors to which the soil is subjected.

Inorganic S composed of water-soluble and adsorbed $SO_4$- is generally believed to be the immediate source for plants. In soil solution, $SO_4$- is present only in small quantity which varies continuously and its concentration at a particular time depends on the balance between plant uptake, fertilizer input, mineralization and immobilization [4]. So, there is no information regarding the vertical distribution of available K and S in Chilkahar block of Ballia district soil for suitability of different extractants under the Inceptisols of Indo-Gangetic plains.

## Materials and Methods

### Study area

Ballia is in India country in the cities place category with the GPS coordinates of 25°45'30.6" N and 84°8'56.0" E. It is situated approx. 59.29 to 64.92 meters mean sea level. The mean annual rainfall ranges from 950-150 mm. The Soil samples collection site was villages, Kureji (P1) and Palta (P2), Chilkahar block lies at 83°59'45" to 84°15'05" E longitude and 25°51'57" to 25°45'48" N latitude with an altitude of 72 meters of mean sea level.

### Soil sampling and analysis

Soil samples were collected from 0-15, 15-30, 30-45, 45-60, 60-75, 75-90, 90-105, 105-120, 120-135 and 135-150 cm depths of two pedon each of both villages *viz*. Kueji and Palta. About 500 g fresh soil sample per soil profile and each depth were collected, processed by air-dried, powdered, and sieved through a 2 mm brass sieve and stored separately in polythene bags for chemical analysis. The collected soil samples were analyzed using the standard method described by different authors. The pH and EC were determined in the 1:2.5 ratio of the soil water suspension method described by Kanwar and Chopra (1998) [5]. The organic carbon content of the soil was determined by Walkley and Black's (1934) [6] rapid titration method. Analysed extractants *viz*. available potassium by Ammonium acetate extractable K method described by Muhr *et al*. (1965) [7], 0.01 M Calcium Chloride extractable K method described by Woodruff and McIntosh (1960), EDTA extractable K method described by Haynes and Swift (1983) [8].

*Table-1 pH, EC and organic carbon in soil of two villages Kureji (P1) and Palta (P2) of Chilkahar Block*

| Depth (cm) | Kureji (P1) | | | Palta (P2) | | |
|---|---|---|---|---|---|---|
| | pH | EC ($dSm^{-1}$) | Organic carbon (%) | pH | EC ($dSm^{-1}$) | Organic carbon (%) |
| 0-15 | 7.2 | 1.003 | 0.37 | 7.4 | 1.004 | 0.40 |
| 15-30 | 6.8 | 1.003 | 0.24 | 7.2 | 1.004 | .0.34 |
| 30-45 | 7.3 | 1.002 | 0.18 | 7.2 | 1.004 | 0.31 |
| 45-60 | 6.8 | 1.003 | 0.15 | 7.0 | 1.003 | 0.24 |
| 60-75 | 6.6 | 1.003 | 0.10 | 6.8 | 1.002 | 0.19 |
| 75-90 | 6.5 | 1.002 | 0.07 | 6.6 | 1.002 | 0.16 |
| 90-105 | 6.6 | 1.002 | 0.06 | 6.6 | 1.001 | 0.10 |
| 105-120 | 6.3 | 1.001 | 0.04 | 6.8 | 1.002 | 0.06 |
| 120-135 | 6.3 | 1.001 | 0.04 | 6.9 | 1.001 | 0.04 |

*Table-2 Status of available potassium (kg ha-1) in soils of Kureji (P1) and Palta (P2) village of Chilkahar block by use of different extractants*

| Depth (cm) | $NH_4OAc$ Extractable - K | | $CaCl_2.2H_2O$ Extractable - K | | EDTA Extractable-K | | Water Extractable-K | | $HNO_3$ Extractable - K | | Mehlich III Extractable-K | | NaCl Extractable-K | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (P1) | (P2) | (P1) | (P2) | (P1) | (P2) | (P1) | (P2) | (P1) | (P2) | (P1) | (P2) | (P1) | (P2) |
| 0-15 | 320.2 | 347.2 | 142.6 | 152.6 | 106.6 | 116.6 | 207.0 | 214.0 | 268.0 | 288.0 | 125.0 | 128.0 | 150.0 | 160.0 |
| 15-30 | 225.2 | 235.2 | 124.2 | 134.2 | 100.0 | 104.0 | 197.0 | 202.0 | 222.4 | 242.4 | 112.6 | 114.6 | 142.0 | 152.0 |
| 30-45 | 236.4 | 246.4 | 113.2 | 123.2 | 100.0 | 104.2 | 190.4 | 195.4 | 217.8 | 237.8 | 113.6 | 114.0 | 146.4 | 158.4 |
| 45-60 | 225.2 | 235.2 | 120.0 | 130.0 | 92.8 | 97.8 | 194.0 | 198.0 | 220.0 | 240.0 | 100.0 | 102.0 | 139.8 | 149.8 |
| 60-75 | 202.6 | 212.6 | 114.0 | 124.0 | 95.0 | 102.0 | 182.0 | 184.0 | 206.2 | 226.2 | 106.4 | 108.4 | 124.0 | 132.0 |
| 75-90 | 189.6 | 201.6 | 108.4 | 118.4 | 80.0 | 94.6 | 167.8 | 176.8 | 192.0 | 212.0 | 94.8 | 92.8 | 112.6 | 124.6 |
| 90-105 | 189.6 | 201.6 | 101.8 | 106.8 | 80.0 | 87.0 | 160.0 | 176.2 | 194.0 | 212.0 | 90.0 | 89.0 | 112.6 | 124.0 |
| 105-120 | 180.4 | 190.4 | 88.6 | 98.6 | 75.8 | 78.8 | 160.0 | 168.0 | 188.0 | 206.0 | 76.0 | 74.0 | 98.2 | 110.0 |
| 120-135 | 169.2 | 179.2 | 88.6 | 88.2 | 66.8 | 69.8 | 169.0 | 170.8 | 190.0 | 206.0 | 78.0 | 66.2 | 98.2 | 110.2 |

*Table-3 Status of available Sulphur (mg kg-1) in soils of Kureji (P1) and Palta (P2) village of Chilkahar block by use of different extractants*

| Depth (cm) | $CaCl_2$ Extractable-S | | $NaHCO_3$ Extractable– S | | KCl Extractable-S | | HCl Extractable-S | | Morgan's reagent Extractable - S | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (P1) | (P2) | (P1) | (P2) | (P1) | (P2) | (P1) | (P2) | (P1) | (P2) |
| 0-15 | 6.2 | 6.3 | 5.0 | 5.0 | 4.8 | 5.2 | 3.0 | 3.0 | 6.6 | 6.8 |
| 15-30 | 6.0 | 6.2 | 5.2 | 5.1 | 4.7 | 5.2 | 2.9 | 3.0 | 6.5 | 6.7 |
| 30-45 | 5.8 | 6.0 | 5.0 | 5.2 | 4.4 | 5.0 | 2.7 | 2.9 | 6.3 | 6.7 |
| 45-60 | 5.9 | 6.1 | 5.1 | 5.0 | 4.5 | 5.1 | 2.7 | 2.8 | 6.4 | 6.6 |
| 60-75 | 5.8 | 5.9 | 5.2 | 5.0 | 4.3 | 5.1 | 2.6 | 2.7 | 6.2 | 6.5 |
| 75-90 | 5.6 | 5.9 | 5.2 | 5.1 | 4.2 | 4.9 | 2.5 | 2.7 | 6.0 | 6.4 |
| 90-105 | 5.4 | 5.8 | 4.9 | 5.1 | 4.1 | 4.8 | 2.4 | 2.6 | 6.0 | 6.4 |
| 105-120 | 5.0 | 5.6 | 5.0 | 4.9 | 4.1 | 4.6 | 2.5 | 2.5 | 6.1 | 6.3 |
| 120-135 | 5.2 | 5.7 | 4.9 | 4.9 | 4.0 | 4.6 | 2.4 | 2.4 | 6.1 | 6.1 |

The water-soluble method was described by Rouse and Bertramson, (1949), Nitric Acid extractable K method described by Wood and Deturk (1940), Mehlich-III extractable K method described by Mehlich (1984), 1M Sodium Chloride extractable K method described by Woodruff and McIntosh (1960). Extactants for available sulphur analysis *viz*. $CaCl_2$ extractable-sulfur was determined by Williams and Steinberg (1969) [9], rapid extraction method. Morgan's reagent extractable S method was described by Chesnin and Yien (1951). 0.5 M $NaHCO_3$ extractable S method was described by Kilmer and Nearpaoo (1996) and Singh and Srivastava (1993). KCl extractable sulphur method described by Bloem *et al*. (2002). HCl extractable Sulphur method described by Little *et al*. (1958).

## Results and discussion

Soil pH and EC - pH and EC [Table-1] of soil from two different pedons of two villages Kureji (P1) and Palta (P2) on 0-15, 15-30, 30-45, 45-60, 60-75, 75-90, 90-105, 105-120 and 120-135 cm soil depth. The soil pH ranged from 7.4 to 6.3 in both pedons. The decreasing range of pH with increasing depth from upper soil at 0-15 cm to lower depth at 120-135 cm. Pedon 1 was showed 7.2 pH at 0-15 cm decrease with depth 6.3 pH at 120-135 cm depth. Pedon 2 was showed 7.4 pH at 0-15 cm after that decreased 6.9 pH at 120-135 cm. Each village was rice-growing areas and water logging had very common might be resulted in low pH. The EC of soil ranged from 1.004 to1.001dSm$^{-1}$ in both pedons. Pedon 1 was showed 1.003 dSm$^{-1}$ at 0-15 cm and 1.001dSm$^{-1}$ at 135-150 cm depth. Pedon 2 was showed 1.004 dSm$^{-1}$ at 0-15 cm and 1.001 dSm$^{-1}$ at 120-135 cm depth, it indicates that not a wide variation among both pedons. The EC was slightly decreased with increasing soil depth. But it has not much more difference among the depth and between the pedon, similar finding has been given by Singh *et al*. (2019) [10].

### Organic carbon (%)

Both pedons of Kueji and Palta village of Chilkahar block soils [Table-1] on 0-15, 15-30, 30-45, 45-60, 60-75, 75-90, 90-105, 105-120, 120-135, and 135-150 cm. Pedon 1 was showed 0.37 % organic carbon content at 0-15 cm decrease with depth 0.03 % at 135-150 cm depth. Pedon 2 was showed 0.40 % organic carbon content at 0-15 cm after that it was decreased to 0.04 % organic carbon content at 120-135 cm. The content of organic carbon was decreased with increasing soil depth in both pedons. The amount of organic carbon content is more in surface soil due to the accumulation of organic substances [11,12].

### Available potassium (kg ha$^{-1}$)

The amount of $NH_4OAc$ extractable-K [Table-2] was ranged from 320 kg ha$^{-1}$ at 0-15 cm soil depth to 170 kg ha$^{-1}$ at 135-150 cm depth; 0.01 M $CaCl_2.2H_2O$ extractable-K was ranged from 142.6 kg ha$^{-1}$at 0-15 cm soil depth to 78.2 kg ha$^{-1}$ at 135-150 cm depth; EDTA extractable-K was ranged from 106.6 kg ha$^{-1}$at 0-15 cm soil depth to 67.8 kg ha$^{-1}$ at 135-150 cm depth; Water extractable-K was ranged from 207.0 kg ha$^{-1}$at 0-15 cm soil depth to 162.0 kg ha$^{-1}$ at 135-150 cm depth; $HNO_3$ extractable-K was ranged from 268.0 kg ha$^{-1}$at 0-15 cm soil depth to 186 kg ha$^{-1}$ at 135-150 cm depth; Mehlich III extractable-K was ranged from 125 kg ha$^{-1}$at 0-15 cm soil depth to 65.2 kg ha$^{-1}$ at 135-150 cm depth; and 1M NaCl extractable-K was ranged from 150.0 kg ha$^{-1}$ at 0-15 cm soil depth to 95.0 kg ha$^{-1}$ at 120-135 cm depth in pedon 1. In pedon 2 $NH_4OAc$ extractable-K was ranged from 347.2 kg ha$^{-1}$ at 0-15 cm soil depth to 179.2 kg ha$^{-1}$ at 135-150 cm depth; 0.01 M $CaCl_2.2H_2O$ extractable-K was ranged from 152.6 kg ha$^{-1}$ at 0-15 cm soil depth to 88.2 kg ha$^{-1}$ at 135-150 cm depth; EDTA extractable-K was ranged from 116.6 kg ha$^{-1}$ at 0-15 cm soil depth to 69.8 kg ha$^{-1}$ at 135-150 cm depth; Water extractable-K was ranged from 214.0 kg ha$^{-1}$ at 0-15 cm soil depth to 170.8 kg ha$^{-1}$ at 135-150 cm depth; $HNO_3$ extractable-K was ranged from 288.0 kg ha$^{-1}$ at 0-15 cm soil depth to 206.0 kg ha$^{-1}$ at 135-150 cm depth; Mehlich III extractable-K was ranged from 128.0 kg ha$^{-1}$ at 0-15 cm soil depth to 66.2 kg ha$^{-1}$ at 135-150 cm depth; and1 M NaCl extractable-K was ranged from 160.0 kg ha$^{-1}$ at 0-15 cm soil depth to 110.2.0 kg ha$^{-1}$ at 135-150 cm depth. Among the extractant for available potassium.

The normal neutral $NH_4OAc$ extractant was found most suitable among the extractant in this soil condition.

**Available Sulphur content (mgkg$^{-1}$)**

The amount of $CaCl_2$ extractable-S [Table-3] was ranged from 6.2 mg kg$^{-1}$ at 0-15 cm soil depth to 5.2 mg kg$^{-1}$ at 120-135 cm depth; $NaHCO_3$ extractable-S was ranged from 5.0 mg kg$^{-1}$ at 0-15 cm depth to 4.8 mg kg$^{-1}$ at 120-135 cm depth; KCl extractable-S was ranged from 4.8 mg kg$^{-1}$ at 0-15 cm soil depth to 4.0 mg kg$^{-1}$ at 120-135 cm depth; HCl extractable-S was ranged from 3.0 mg kg$^{-1}$ at 0-15 cm soil depth to 2.3 mg kg$^{-1}$ at 120-135 cm depth; and Morgan's reagent extractable-S was ranged from 6.6 mg kg$^{-1}$ at 0-15 cm soil depth to 6.0 mg kg$^{-1}$ at 120-135 cm depth in pedon 1. In pedon 2 $CaCl_2$ extractable-S was ranged from 6.3 mg kg$^{-1}$ at 0-15 cm soil depth to 5.7 mg kg$^{-1}$ at 120 -135 cm depth; $NaHCO_3$ extractable-S was ranged from 5.0 mg kg$^{-1}$ at 0-15 cm depth to 4.9 mg kg$^{-1}$ at 120 -135 cm depth; KCl extractable-S was ranged from 5.2 mg kg$^{-1}$ at 0-15 cm soil depth to 4.6 mg kg$^{-1}$ at 120-135 cm depth; HCl extractable-S was ranged from 3.0 mg kg$^{-1}$ at 0-15 cm soil depth to 2.4 mg kg$^{-1}$ at 120-135 cm depth; Morgan's reagent extractable-S was ranged from 6.8 mg kg$^{-1}$ at 0-15 cm soil depth to 6.1 mg kg$^{-1}$ at 120-135 cm depth. Among the extractant for available sulphur [13,14]. A greater amount of available sulphur was found in surface soil than sub-surfaces soil resulting from its recycling over the years by plant and subsequent organic matter accumulation [15, 16]. The release of available sulphur was the highest amount by use of Morgan's reagent extractant among the different extracts of that soil condition.

**Conclusion**

The use of different extractant to release of available potassium and sulphur in soil of Kureji and Palta village of Chilkahar block showed that maximum release of available K by neutral $NH_4OAc$ extractant among the extractants in both pedon while maximum amount of available S was found by $CaCl_2$ extractant among the extractants.

**Application of research:** The vertical distribution of available potassium and sulphur under the different soil properties are helpful to provide the information of each horizon of soil profile and their morphological and pedological nature.
Use for land use planning and prospects of particular soil.

**Research Category:** Soil Science for pedology and edaphology

**Abbreviations:** P1-Pedon 1, P2-Pedon 2

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**Author statement:** All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

**Study area / Sample Collection:** Two village of Chilkahar bock of Ballia district

**Cultivar / Variety / Breed name:** Nil

**Conflict of Interest:** None declared

**Ethical approval:** This article does not contain any studies with human participants or animals performed by any of the authors.

Ethical Committee Approval Number: Nil

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